^{53}MN-^{53}CR ISOTOPE SYSTEMATICS OF THE HED PARENT BODY.

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Our recent studies of ^{53}Mn-^{53}Cr isotope systematics ($T_{1/2}$ of ^{53}Mn is 3.7 Ma) in chondrites, non-cumulate eucrites, Mars, and the Moon have shown the presence of a radial gradient in the abundances of radiogenic ^{53}Cr in the solar system [1]. We have suggested that this gradient may be the result of an original heterogeneous distribution of ^{53}Mn at different heliocentric distances. While the Earth and the Moon at 1 AU are characterized by the same ^{53}Cr/^{52}Cr ratios (0ε; 1ε = $1x10^{-4}$), Mars (1.51AU) exhibits a ^{53}Cr excess of ~0.22ε, and the ordinary chondrites (asteroid belt, 2-3AU?) reveal a ^{53}Cr excess of ~0.48ε. Based on the study of the eucrite Caldera, which has equilibrated Cr isotopes [2], we assigned to the HED parent body (HED PB) (Vesta, 2.36 AU) a ^{53}Cr/^{52}Cr excess of 1.12ε. As we noted in [1], however, if Mn/Cr has fractionated very early in the history of the HED PB, with a bulk model Mn/Cr ratio close to chondritic [3], this planetesimal may actually have a much smaller ^{53}Cr excess. In order to a) learn more about the evolutionary time scale of the HED PB and b) constrain further the extent of ^{53}Mn heterogeneity within the asteroid belt itself and, thus, to determine whether the ^{53}Mn-^{53}Cr isotope system can be used as a chronometer for different asteroid belt materials, we have studied other constituents of the HED PB - diogenites, cumulate and several additional non-cumulate eucrites.

We have measured ^{53}Cr/^{52}Cr and Mn/Cr ratios in bulk rocks, chromites, and bulk silicates from the diogenites Johnstown [JT] and Shalka [SHA]. Similar to Caldera [CAL], both meteorites show equilibrated Cr isotopic composition: within the uncertainties (5-10 ppm) the phases with different ^{55}Mn/^{52}Cr have the same ^{53}Cr/^{52}Cr ratios. However, the ^{53}Cr excesses in JT (~0.58ε) and SHA (~0.39ε) were found to be significantly lower than those in Caldera. This indicates that Mn/Cr fractionation in the HED PB mantle has occurred very early in the history of the solar system and that the ^{53}Cr excess in CAL does obviously not represent that of the bulk HED PB. The data for the diogenites, the cumulate eucrite Serra de Magé [SM], an anomalous, high -Mg -REE eucrite Pomozdino [POM], and the non-cumulate eucrite Ibitira [IBI] are summarized in the Figure. The data obtained earlier for Caldera, Chervony Kut [CK], and Juvinas [JUV] are also included.

In the Figure we plotted the measured ^{53}Cr/^{52}Cr ratios for the *bulk* meteorites versus their respective ^{55}Mn/^{52}Cr ratios. With the exception of CK, all data points form a well defined correlation line. Because this line represents a *bulk* meteorite isochron it bears no information on the time of crystallization or cooling of individual meteorites. Instead, the slope of the line represents the ^{53}Mn/^{55}Mn ratio at the time of the *last Mn/Cr fractionation* in the HED mantle and corresponds to $(4.6\pm0.6) \times 10^{-6}$. The absence of scatter of the data points from the line indicates that the source reservoirs of all these meteorites were formed contemporaneously and that the Mn-Cr systems of the bulk samples of these meteorites remained closed since their formation. We note, however, that the closer the ^{55}Mn/^{52}Cr ratio of a bulk meteorite falls to the chondritic value (0.76) the smaller becomes the time resolution. For example, material with a ^{55}Mn/^{52}Cr ratio of 2 which was separated from a chondritic source (see below) 3 Ma after the other meteorites would result in an offset of -0.25ε from the isochron while the corresponding offset for a ^{55}Mn/^{52}Cr ratio of 0.8 would only be -0.01ε and would go undetected. On the other hand, the offset of CK, with its high ^{53}Mn/^{55}Mn ratio of $(4.3\pm0.4) \times 10^{-6}$ derived from an internal isochron, is most probably the result of a slightly earlier separation of its source from the mantle, whereas its crystallization occurred almost contemporaneously with the global differentiation of the HED PB.

The fact that the isochron passes close to the chondritic point (~0.5ε at 0.76) suggests that the Mn/Cr ratio of the HED PB is indeed close to chondritic. To be exact, the HED PB ^{53}Cr/^{52}Cr ratio is ~0.57ε and is only marginally higher than that in chondrites (~0.48ε) and those calculated for

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the angrite (~0.48ε) and pallasite parent bodies (~0.52ε [4]). Thus, the difference in the $^{53}Cr/^{52}Cr$ ratios and, therefore, in original ^{53}Mn abundances among the asteroid belt objects studied so far is marginal, if it exists at all. The ^{53}Mn-^{53}Cr isotope system, therefore, can be used as a chronometer for samples from within the asteroid belt. From the $^{53}Mn/^{55}Mn$ of (4.6±0.6) x 10^{-6} and that of LEW86010 (LEW), (1.25±0.07) x 10^{-6}, we calculate a relative time of the HED PB mantle fractionation of 7.0±0.8 Ma before LEW. Using the absolute age of LEW (4557.8±0.4 Ma [5]) we convert the relative age into an absolute age and obtain 4564.8±0.9 Ma. Finally, the ^{53}Cr gradient [1] is now a linear function of the heliocentric distance.

From the ^{53}Mn-^{53}Cr isotope systematics in the HED PB we can calculate the lower limit for the age of the solar system. Clearly, the solar system initial $^{53}Cr/^{52}Cr$ (SSI) cannot be higher than the terrestrial $^{53}Cr/^{52}Cr$. Assuming the terrestrial $^{53}Cr/^{52}Cr$ (0ε) ≡ SSI we calculate the time required to evolve $^{53}Cr/^{52}Cr$ in a chondritic source from 0ε to 0.26ε (the HED mantle $^{53}Cr/^{52}Cr$ at 4564.8 Ma) to be ~3.2 Ma. Therefore, the minimum age of the solar system is ~4568 Ma. This value agrees with the upper limit for the absolute age of CAI's (4566±2.0 [6]). A similar calculation using chondritic $^{53}Cr/^{52}Cr$ of 0.48ε yields a minimum solar system age of ~4567.2.

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References: [1] Lugmair G.W. et al.(1996), LPSC XXVII, 785. [2] Wadhwa M. and Lugmair G.W. (1995), Meteoritics **30**, 592. [3] Dreibus G., Wänke H. (1979), LPS **X**, 315 and (1980), Z. Naturforsch. **35a,** 204. Drake M. *et al.* (1989), GCA **53**, 2101. [4] Shukolyukov A. and Lugmair G.W. (1997), (this volume). [5] Lugmair G.W. and Galer S.J.G. (1992), GCA **56**, 1673. [6] Göpel Ch. et al. (1991), Abstr. 54th Meteor. Soc., 73.

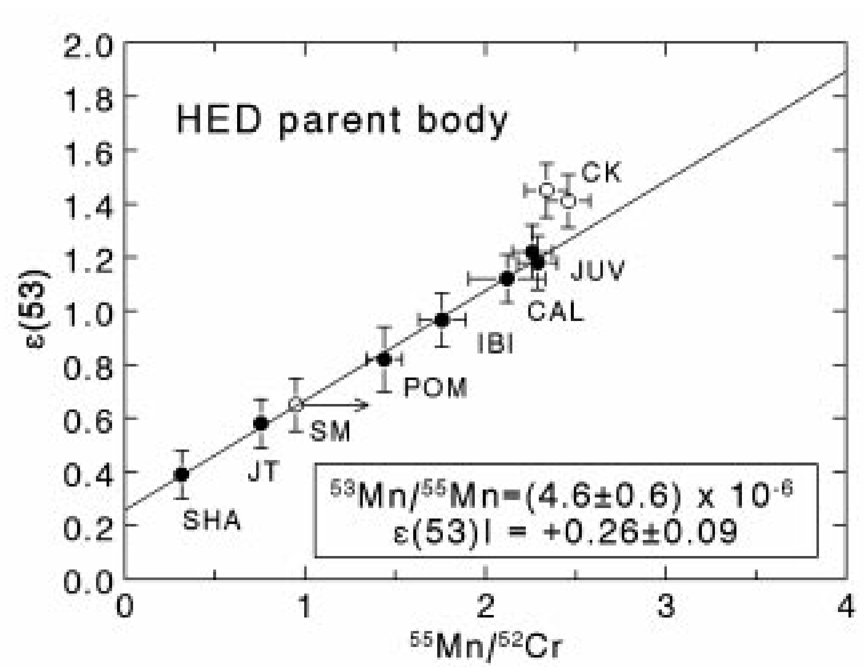

Figure: ^{53}Mn-^{53}Cr isotope systematics in the HED parent body. CAL - Caldera, CK - Chervony Kut, IBI - Ibitira, JT - Johnstown, JUV - Juvinas, POM - Pomozdino, SM - Serra de Magé, SHA - Shalka. The excesses of ^{53}Cr in the bulk rock eucrite and diogenite samples (relative to the terrestrial value) are expressed in ε units (1 part in 10^4) - typical errors are 0.05 to 0.10 ε. A well-defined correlation of $^{53}Cr/^{52}Cr$ with $^{55}Mn/^{52}Cr$ indicates that the sources of the eucrites and diogenites were separated from the HED mantle contemporaneously. The CK and SM data points (the Mn/Cr ratio for SM is poorly constrained) were not included in the calcu-lation of the best fit line. The slope of the isochron defines a $^{53}Mn/^{55}Mn$ ratio of (4.6±0.6) x 10^{-6} at the time of mantle fractionation. The difference between the $^{53}Mn/^{55}Mn$ ratio at the time of Mn/Cr fractionation in the HED mantle and solidification of the angrite LEW86010 corresponds to a time difference of 7.0±0.8 Ma. The absolute Pb-Pb age of LEW86010 is 4557.8±0.4 [5]. Combining these ^{53}Mn-^{53}Cr and Pb-Pb data yields a time of HED mantle fractionation of 4564.8±0.9 Ma.